M-DG Seminar:
Multinomial Processing Tree Modeling

Introduction

Summer semester 2020

Prof. Dr. Daniel Heck

M-DG: Multinomial Processing Tree Modeling

Part	Date	Topic	Literature
(A) Theory	Self study	A1) Introduction	Erdfelder et al. (2009)
		A2) Basics of MPT modeling	Batchelder & Riefer (1999)
		A3) The software multiTree	Moshagen (2010)
		A4) Hierarchical MPT modeling	Lee (2011) Heck et al. (2018)
(B) Application	15.5.*	B1) Questions & Practice with multiTree	Batchelder & Riefer (1986)
	20.5.*	B2) Workflow: Developing an MPT model	Jung et al. (2019)

* Web-Conference, 12:00 – 15:00, https://webconf.hrz.uni-marburg.de/b/dan-fvk-ha6

Introduction & Examples

Overview:

1. Introduction: Measuring recognition memory
2. Example: Source memory
3. Example: Automatic use of stereotypes
4. Summary & Outlook
5. Appendix: More applications

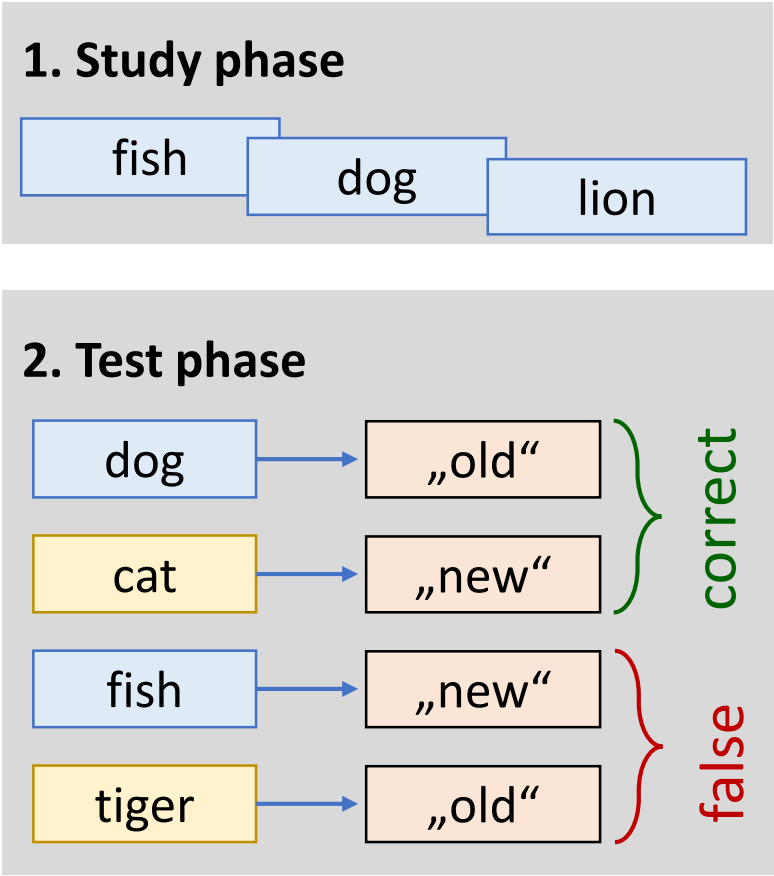
Introduction to MPT Models

- Required type of data: Multinomial models are tailored to discrete, categorical data
  - yes/no responses
  - correct/incorrect judgments
  - multiple choice tasks
  - number or type of recalled words
  - …
- Psychological data are typically discrete in nature
  - If not, they can often be transformed into discrete data
  - Response time bins, rankings of numerical judgments, …

→ many psychological paradigms generate frequency data appropriate for MPT modeling.

Example: Recognition Memory

- Paradigm:
  - Old-new recognition memory test
- Two Conditions:
  - Old items (targets)
  - New items (lures)
- Categorical (dichotomous) dependent variable:
  - „old“ vs. „new“ judgment

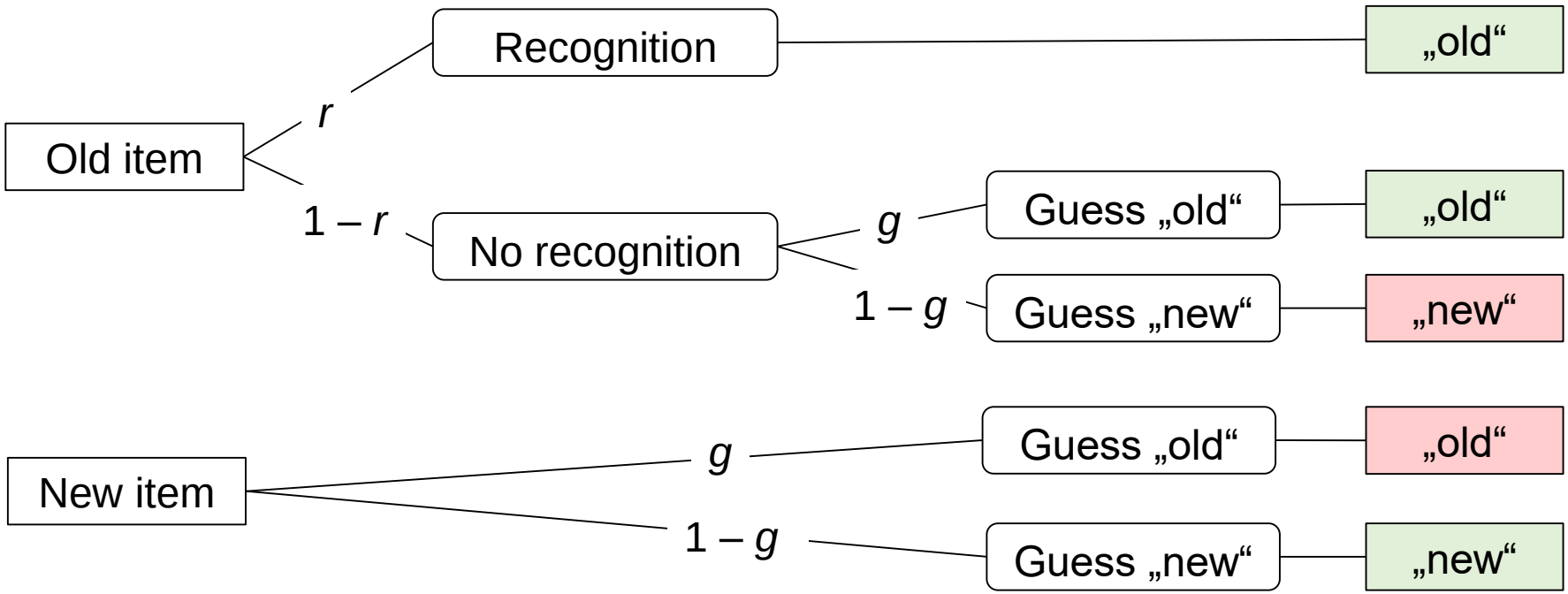


Measurement of Cognitive Processes

MPT models…

- … provide explanations of observed frequency data in terms of basic parameters with clear-cut psychological interpretations;
- … these parameters represent probabilities of latent psychological processes (or latent psychological states) underlying human behavior;
- … in other words, these models disentangle and measure the contributions of different psychological processes to frequencies of observable behaviors.

1-High Threshold Model (Blackwell, 1963)

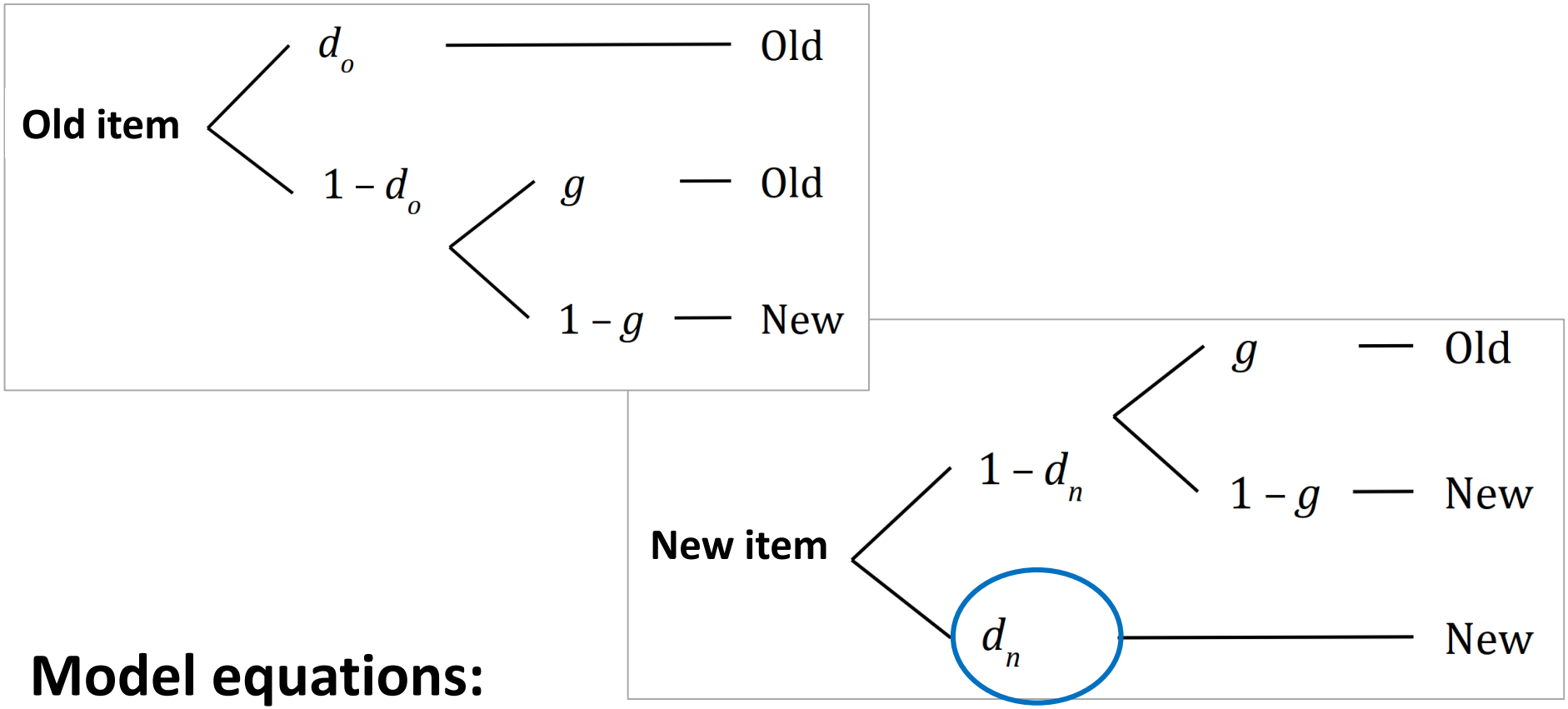


Model equations:

$P(\text{„old“} \mid \text{old item}) = r + (1 - r) \cdot g$

$P(\text{„old“} \mid \text{new item}) = g$

2-High Threshold Model



Model equations:

$P(\text{„old“} \mid \text{old item}) = d_o + (1 - d_o) \cdot g$

$P(\text{„old“} \mid \text{new item}) = (1 - d_n) \cdot g$

Terminology

- "**Multinomial**"
  - MPT models assume that observations are sampled independently from one or more multinomial distributions
  - The frequency data structure can be univariate or multivariate
- "**Processing**"
  - Assumption that a finite number of latent processes generate the observed responses
  - Goal: Drawing inferences about these processes (e.g., via parameter estimation or hypothesis testing)
- "**Tree**"
  - Models can be depicted as probability trees

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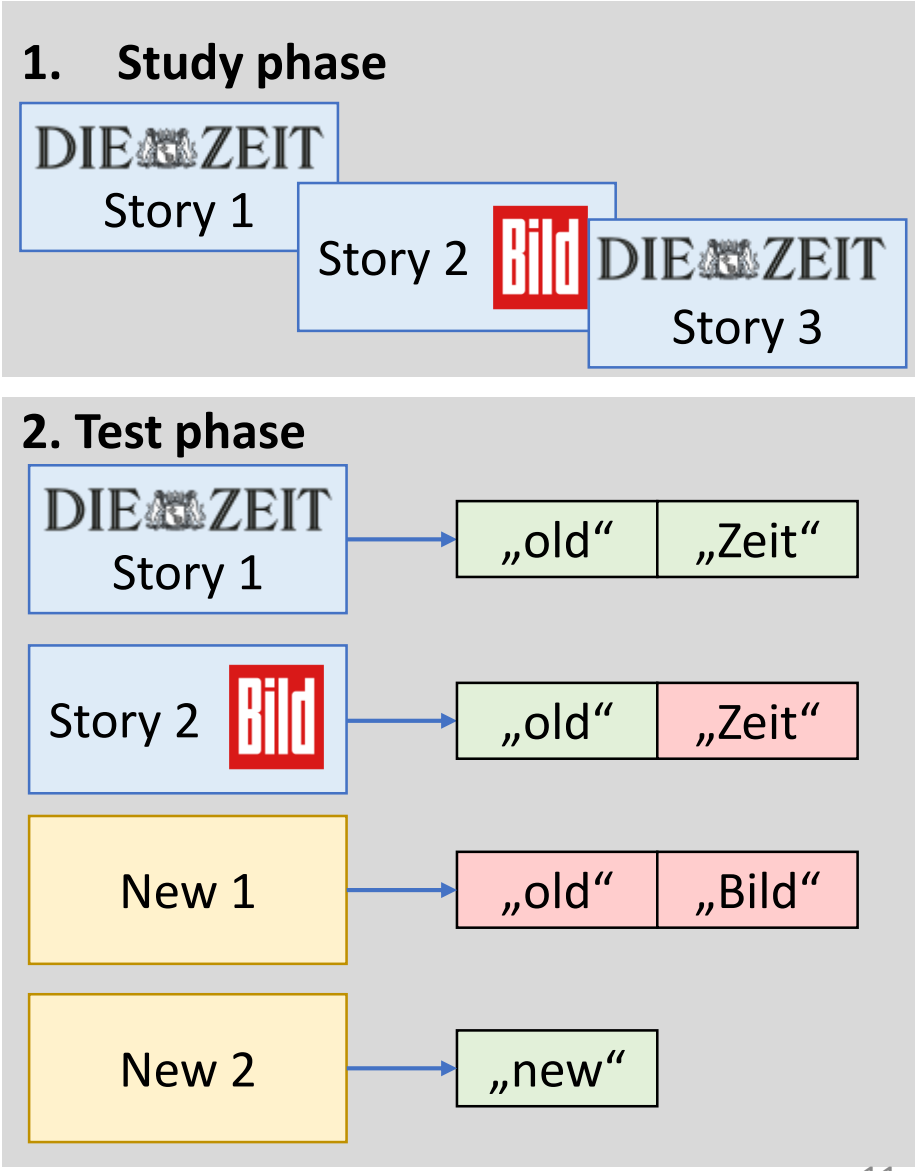
Source Memory

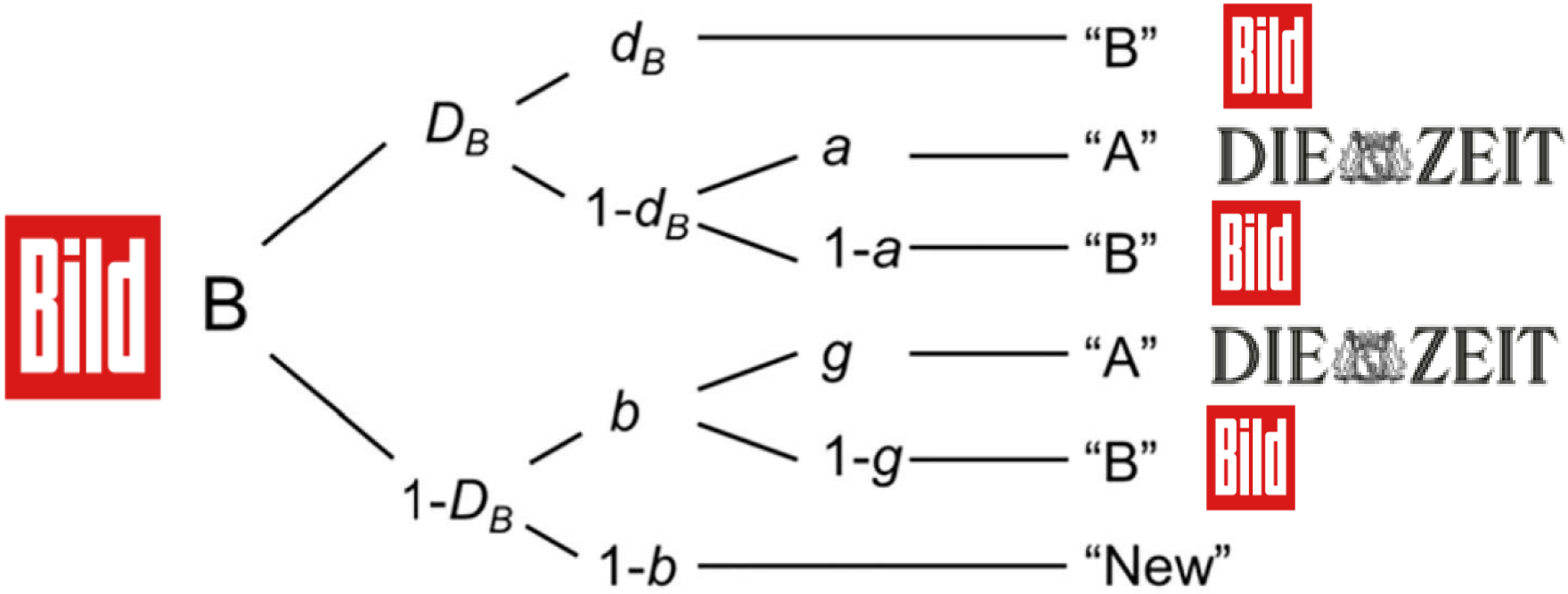
- Paradigm:
  - Source-monitoring task
    with two Sources A & B
    (e.g., A = Zeit, B = Bild)
- Conditions:
  - Test items from Source A or B, and New items
- Dependent variable:
  - Participants' responses whether an item is:

  a) "old" or "new"

  b) from Source "A" or "B"



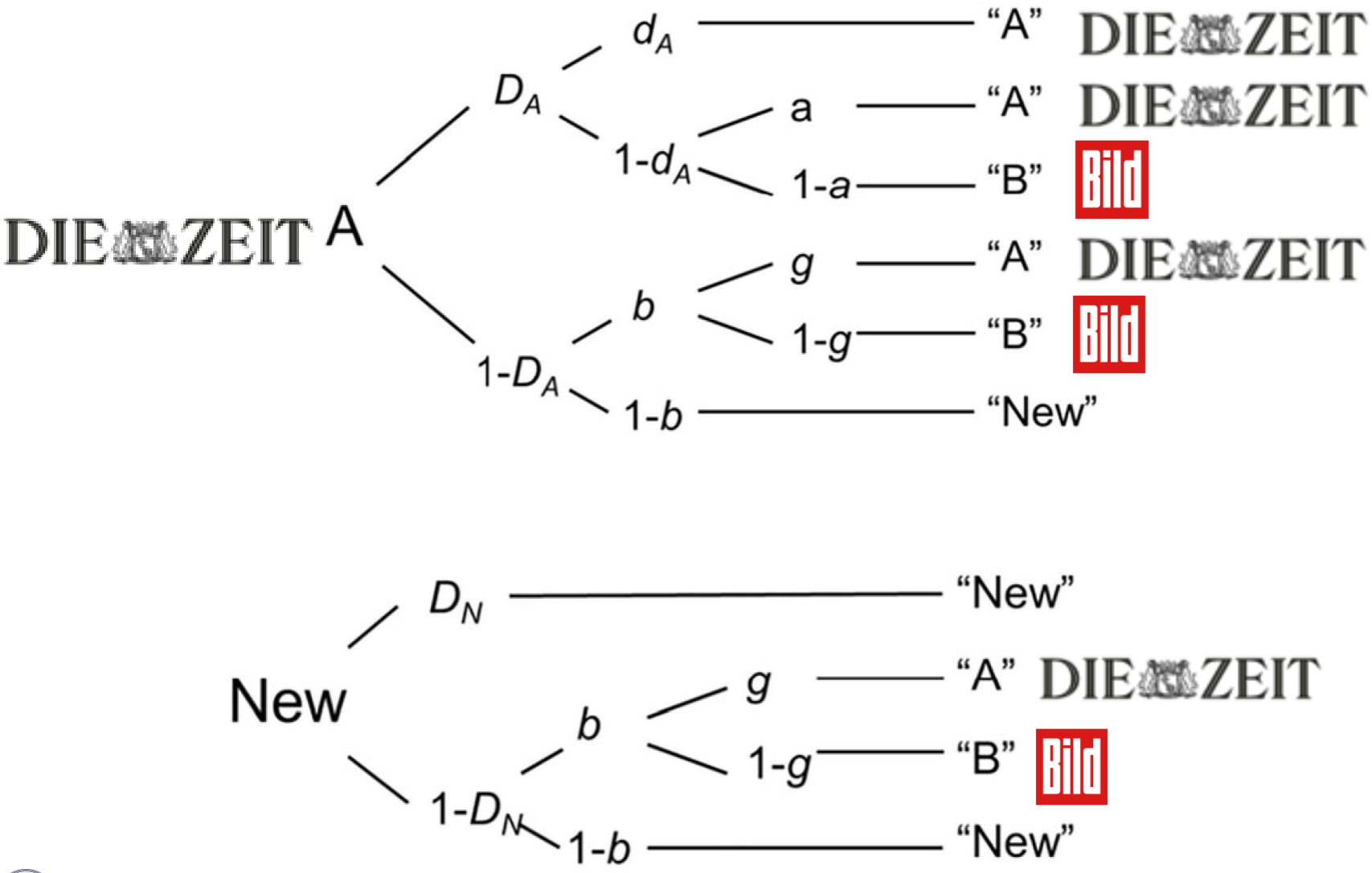
Source-Monitoring Model: Part I



Parameters:

- *D* = item memory
- *d* = source memory
- *b* = guessing "old" (vs. "new")
- *a, g* = guessing Source "A"

Source-Monitoring Model: Part II



Relevance: Reality monitoring

- Reality monitoring:
  - Can a person differentiate between memories of perceived and imagined events?
  - Thought disorders associated with schizophrenia may be a result of reality-monitoring failures
- Reality-monitoring task
  - Source A = say written words out loud
  - Source B = think of the written words for themselves
- Harvey (1985) compared five groups:
  - Manic & schizophrenic patients that are either thought-disordered or non-thought-disordered (TD vs. NTD)
  - Healthy controls

Schizophrenic Patients: Data

- For each group, 3 x 3 frequencies were observed
  - Sources: Say, Think, New
  - Responses: “say”, “think”, “new”

Table 3
Group 3 × 3 Data Tables Constructed From Harvey (1985)

	Manic subjects						Schizophrenic subjects						Normal subjects		
	NTD			TD			NTD			TD					
Item	S	T	N	S	T	N	S	T	N	S	T	N	S	T	N
Say	22	27	31	43	6	31	13	21	46	44	10	26	23	22	35
Think	7	54	19	20	15	45	4	42	34	32	8	40	9	45	26
New	4	26	50	5	9	66	6	20	54	24	7	49	7	10	63

Note. NTD = non-thought disordered; TD = thought disordered; responses are as follows: S = say; T = think; N = new.

Schizophrenic Patients: Model-Based Results

- Reanalysis with the Source Monitoring Model (Batchelder & Riefer, 1990):

Parameter Estimates and Goodness-of-Fit Tests for Harvey's (1985) Experiment

Group	Parameter estimate					Goodness-of-fit
	D_1	D_2	d	b	g	$G^2(1)$
Manic NTD	.39	.62	.51	.37	.17	0.50
Manic TD	.53	.29	.43	.18	.69	9.94*
Schizophrenic NTD	.11	.36	.87	.34	.21	0.25
Schizophrenic TD	.47	.18	.03	.39	.80	0.18
Normal	.44	.59	.42	.21	.30	1.20

Note. D_1 = detectability of say items, D_2 = detectability of listen items, d = source discriminability; b = bias for responding "old"; g = guessing that the item is a say item; TD = thought disordered; NTD = non-thought disordered.
* $p < .01$.

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Weapon Identification Task (WIT)

- Paradigm (Payne, 2001):
  - Sequential priming procedure
- Conditions:
  - 2x2 within-subjects design
  - Prime: White vs. black face
  - Target: Weapon vs. tool
- Categorical dependent variable:
  - Participants' responses whether a presented item is a "weapon" or a "tool"

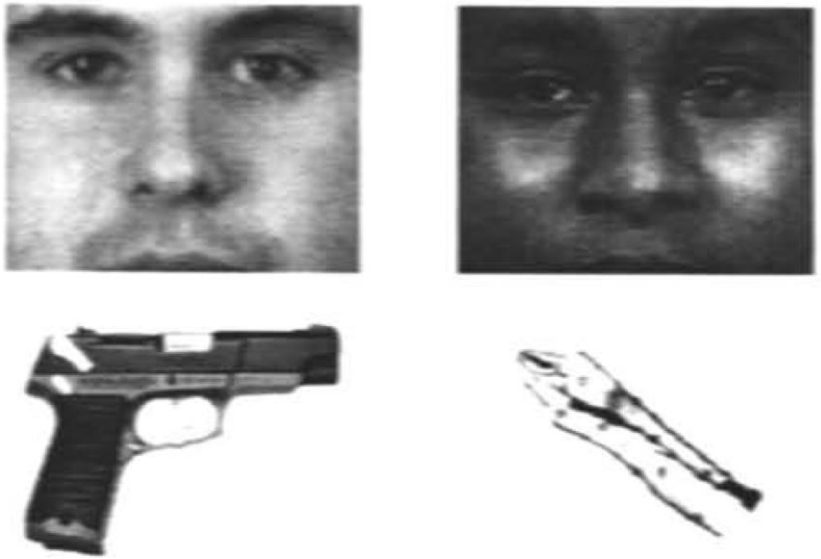
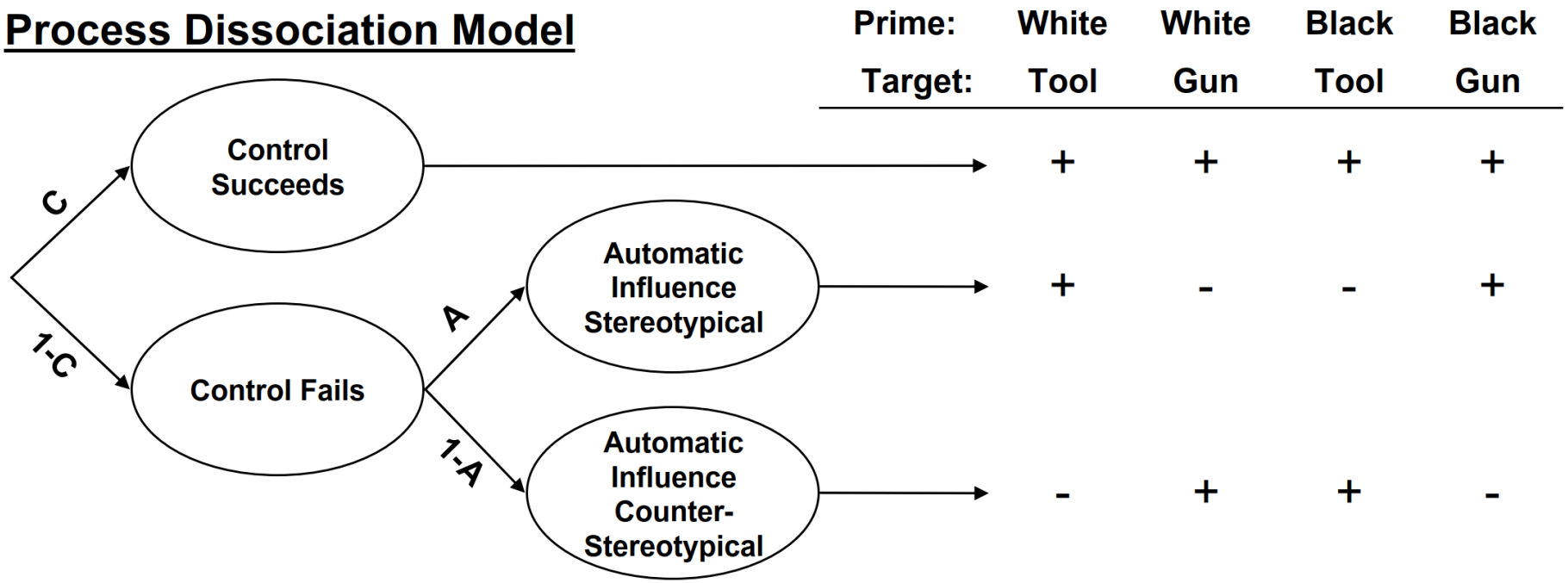


Figure 1. Examples of prime and target stimuli.

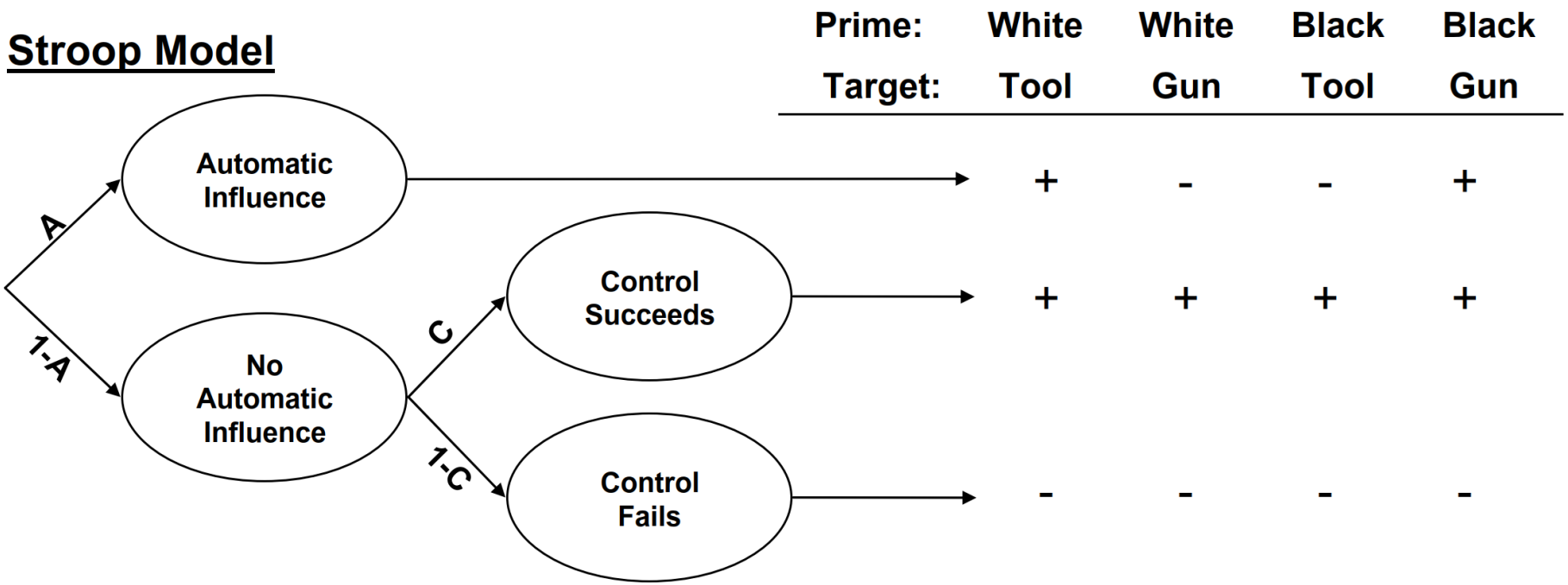
WIT: Process-Dissociation Model (Payne, 2001)



Parameters

- *C* = probability that control succeeds
- *A* = conditional probability that stereotype is automatically activated

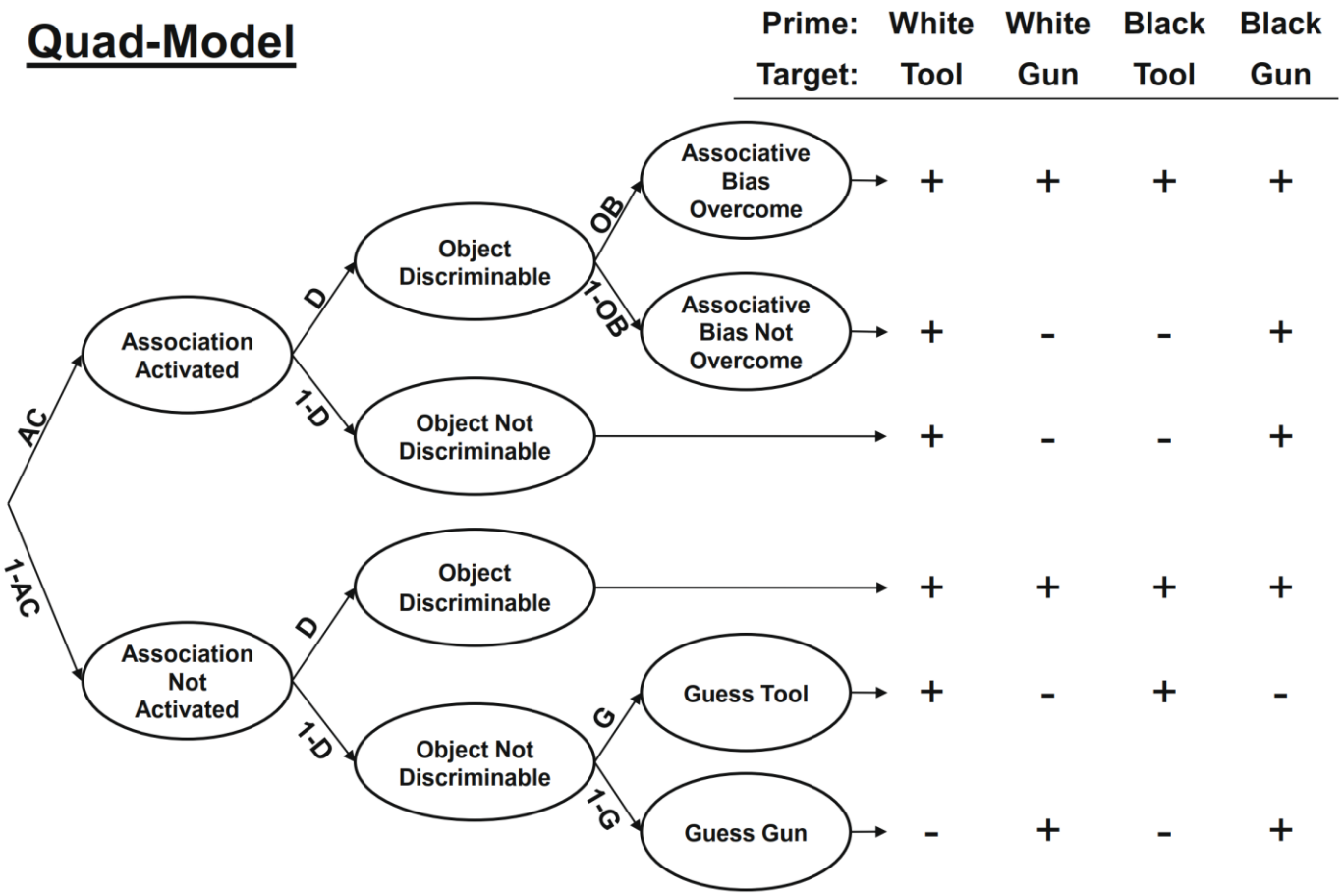
WIT: Stroop Model (Bishara & Payne, 2009)



Parameters

- *A* = probability that stereotype is automatically activated
- *C* = conditional probability that control succeeds

WIT: Quad Model (Conrey et al., 2005)

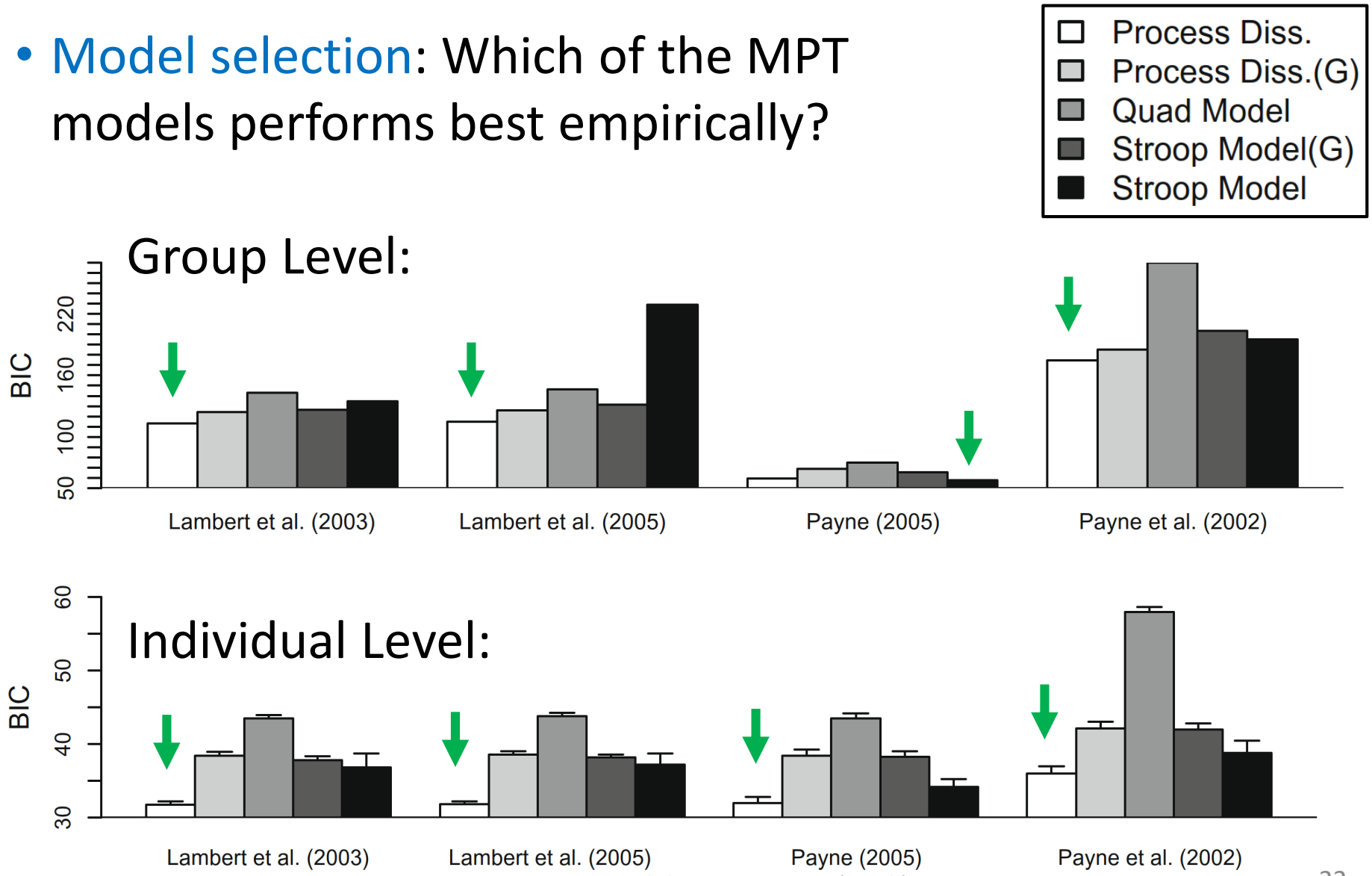


Parameters

- *AC* = stereotype activation
- *D* = object discrimination
- *OC* = overcoming bias

Weapon Identification Task (WIT)

- Model selection: Which of the MPT models performs best empirically?



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Summary

MPT models…

- … explain discrete, categorical data (frequencies)
- … are tailored to specific paradigms & theories
  - Benefit: Psychological theories are specified more precisely.
- … can be applied in various ways
  - Measure the probability of certain psychological processes
  - Test the effect of experimental manipulations
  - Compare different groups of participants
  - Test different theoretical accounts (= different models)

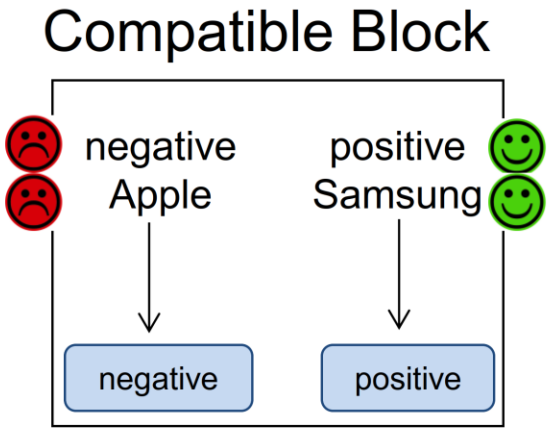
Outlook: Model Development

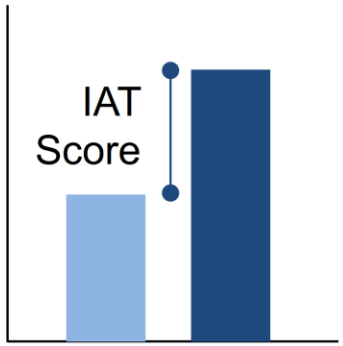
- How are MPT models developed?
  1. Select a paradigm (e.g., a task)
  2. Define the conditions of the paradigm
  3. Define the category system for each condition
  4. List relevant processes/parameters
  5. Construct theoretically reasonable processing branches („trees“) for each condition
  6. Derive corresponding model equations.
- How are MPT models tested?
  - Model fit: Model predictions should be in line with the data
  - Construct validity: Experimental validations should selectively influence specific, theoretically relevant parameters

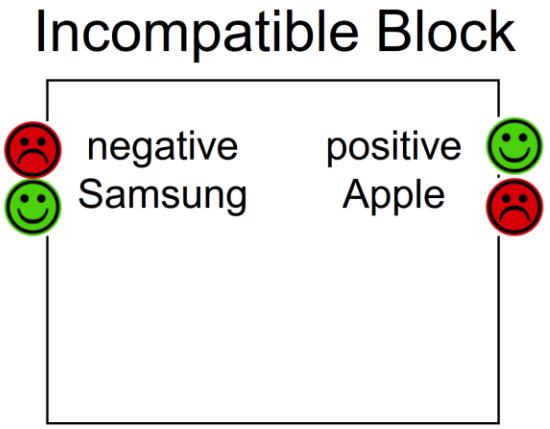
Appendix

More MPT applications….

Implicit Association Test (IAT)







→ simplified task

→ no simplification

Samsung:

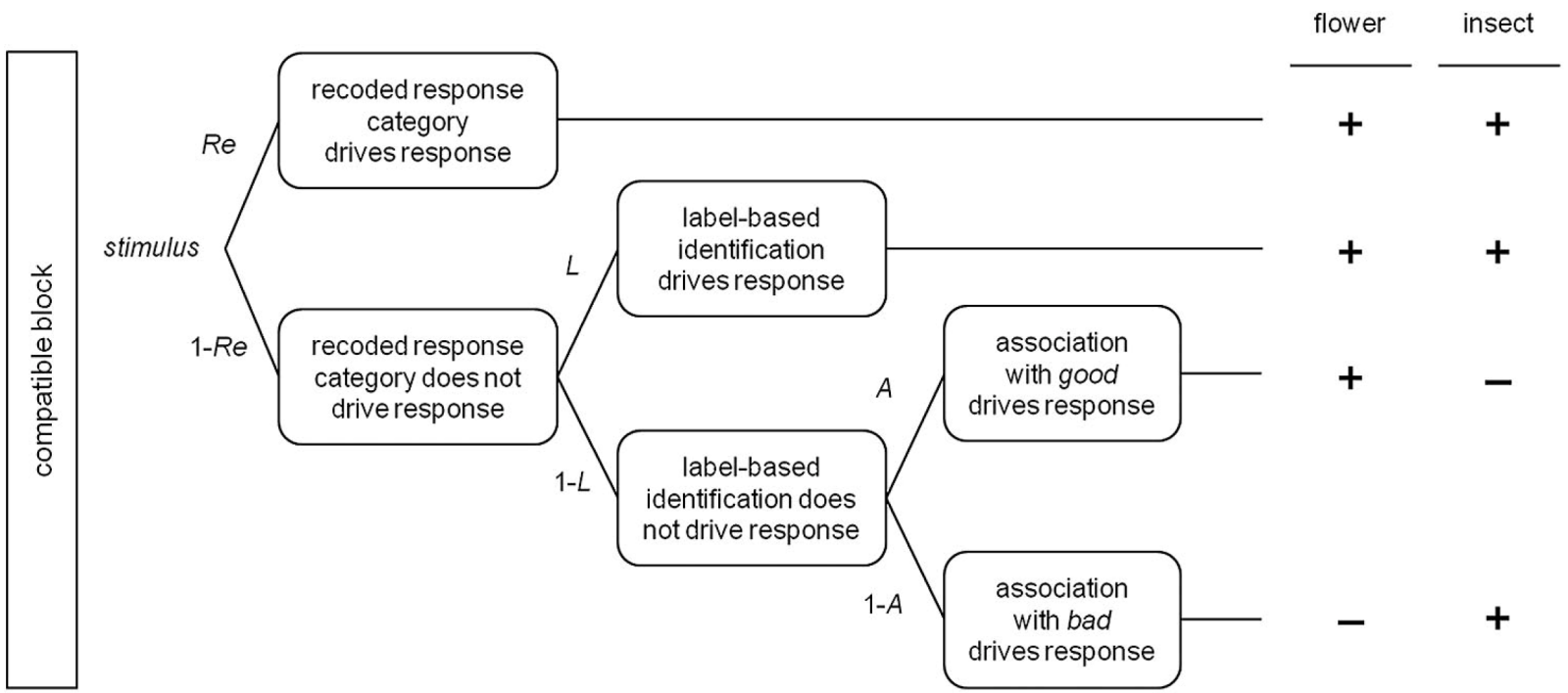
Apple:

positive: peace, love, vacation

negative: war, murder, bomb

(slides by Franziska Meissner)

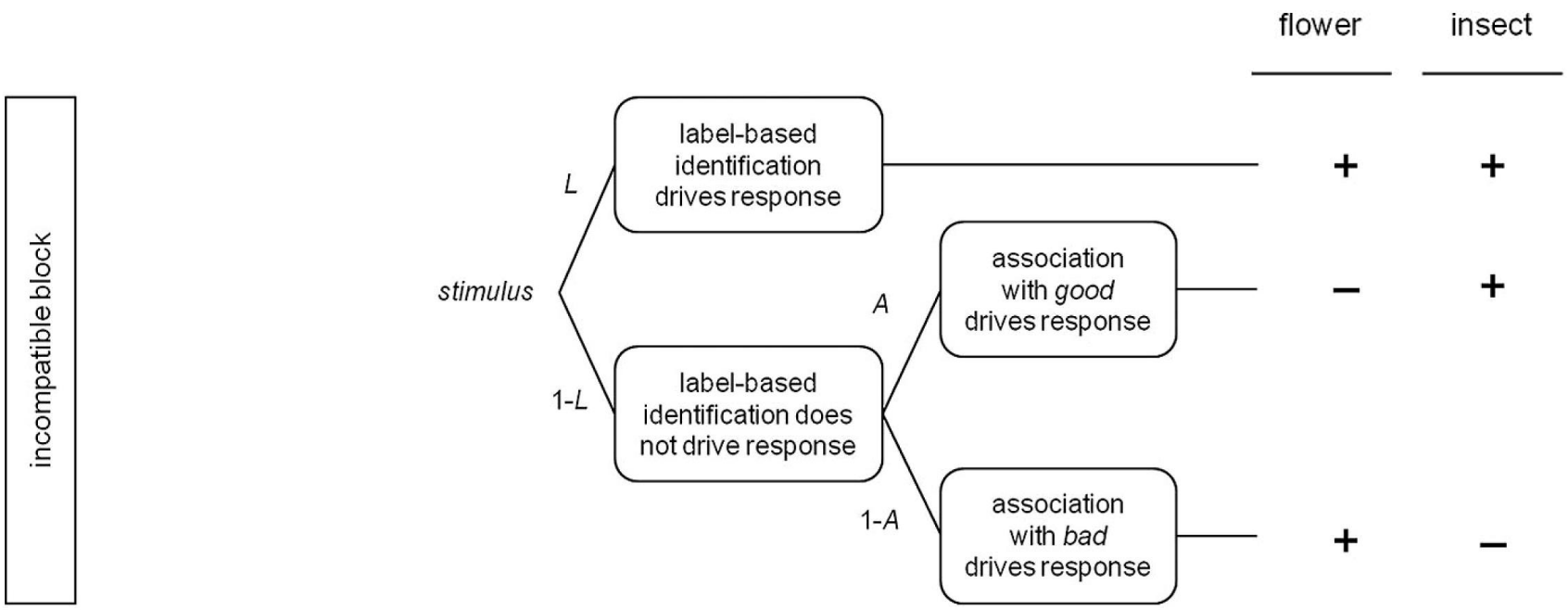
IAT: ReaL Model (Meissner & Rothermund, 2013)



Parameters:

- *Re* = recoding
- *A* = evaluative association
- *L* = identification

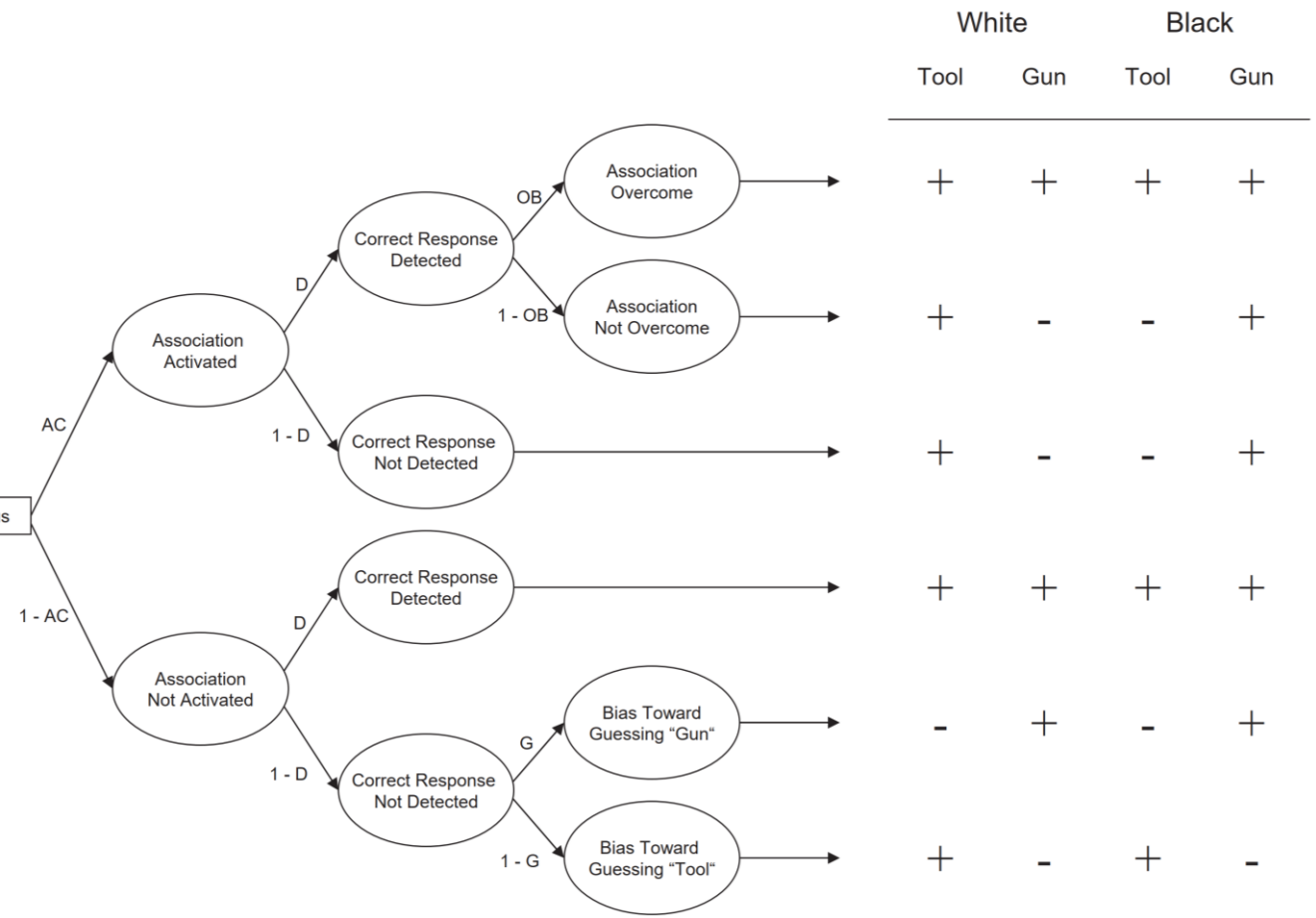
IAT: ReaL Model (Meissner & Rothermund, 2013)



Parameters:

- *Re* = recoding
- *A* = evaluative association
- *L* = identification

Quad Model (Sherman et al., 2008)



	White		Black	
	Tool	Gun	Tool	Gun
	+	+	+	+
	+	-	-	+
	+	-	-	+
	+	+	+	+
	-	+	-	+
	+	-	+	-

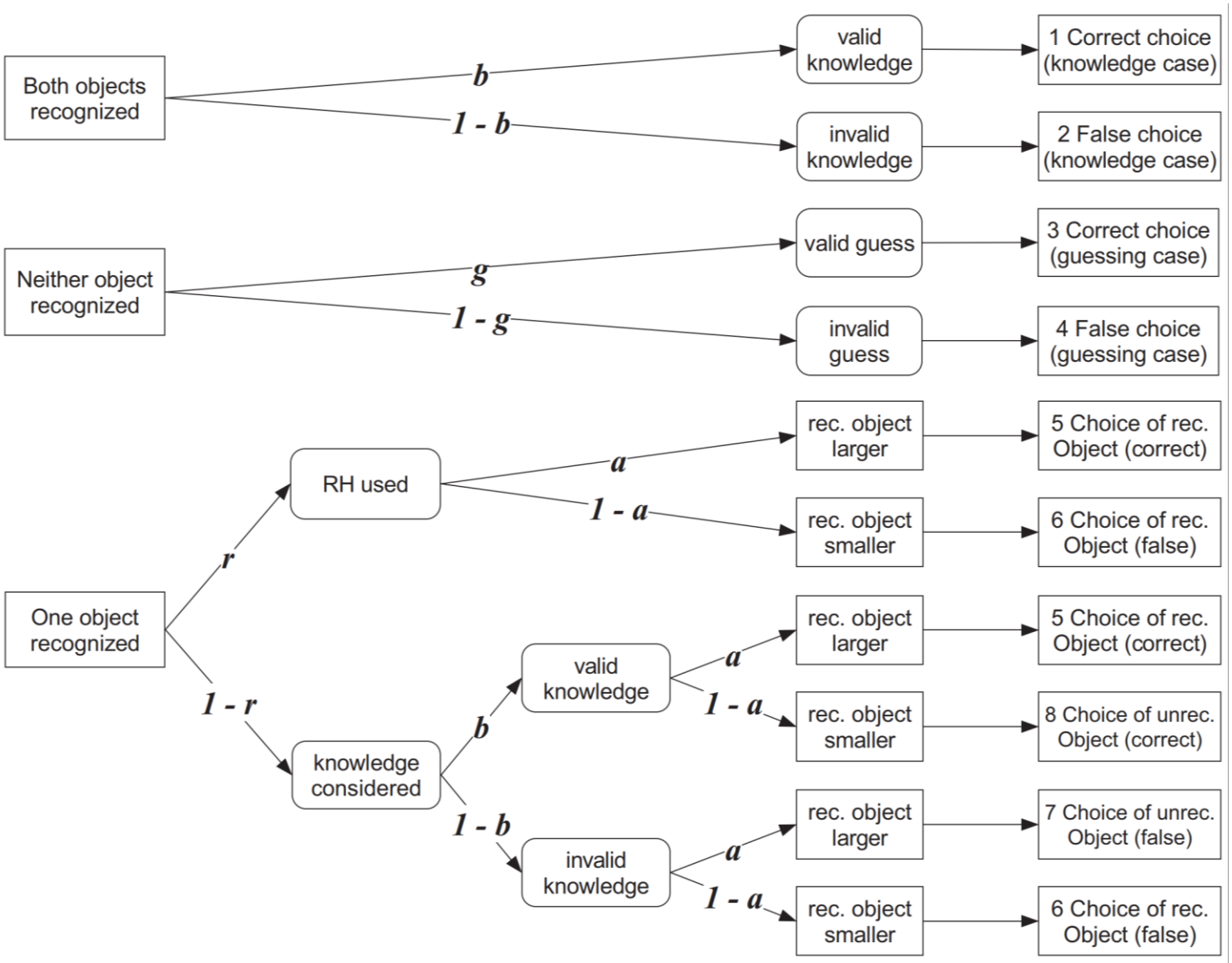
Parameters:

- *AC* = stereotype association
- *D* = discrimination
- *OB* = overcoming bias

Recognition Heuristic (Goldstein & Gigerenzer, 2002)

- Paradigm:
  - Decision phase: “Which city is bigger: Peking or Zhengzhou?”
  - Recognition phase: “Do you know Peking?”
- Conditions:
  - Both items recognized
  - One item recognized
  - None of the items recognized
- Dependent variable:
  - Participants’ responses which city is bigger

Recognition Heuristic: The r-Model (Hilbig et al., 2010)



Parameters:

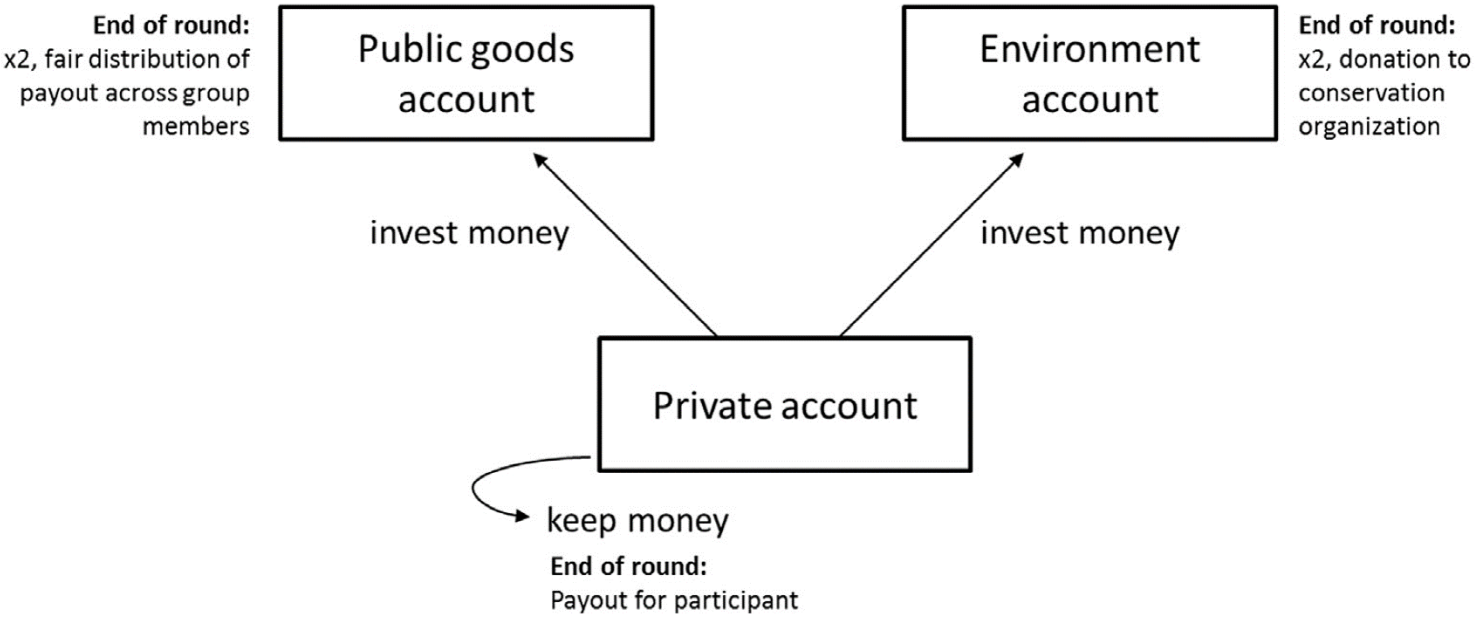
- *r* = recognition heuristic
- b = knowledge
- *a* = recognition validity
- *g* =guessing

Environmental Psychology

- "Which is the greater good? A social dilemma paradigm disentangling environmentalism and cooperation"
  - Klein, Hilbig, & Heck (2017). *Journal of Environmental Psychology*
- Research question: How can we distinguish three types of behavior?
  - Pro-environmental behavior
  - Pro-social behavior
  - Selfish behavior

The Greater Good Game (Klein et al., 2017)

- Variant of a nested public goods game
- Participants decide whether to
  a) keep the money for themselves
  b) contribute it to a public goods account
  c) contribute it to an environment account



The Greater Good Game: MPT Model (Klein et al., 2017)

- MPT model for the Greater Good Game:
  - Parameter *s* = probability of selfish behavior
  - Parameter *e* = probability of pro-environmental behavior